Retroperitoneal nonresective staple exclusion of abdominal aortic aneurysms: Clinical outcome and fate of the excluded abdominal aortic aneurysms

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Purpose: The purpose of this article was to prospectively study analyses outcome after staple exclusion of abdominal aneurysms with specific follow-up of the excluded aneurysm. Whether these data may predict behavior of aneurysms excluded from the circulation by transluminal grafting procedures is also addressed.

Methods: Staple exclusion of abdominal aneurysms with bypass via retroperitoneal incisions was performed in 100 consecutive patients undergoing elective procedures. Risk factors, clamp time, operative time, transfusions, length of stay, complications, platelets, fibrinogen, and fibrin split products were documented. Duplex imaging was performed quarterly for 1 year after exclusion and at least annually thereafter. Serial measurements of aneurysm size and evaluation for thrombosis was obtained.

Results: Aneurysm size averaged 5.5 cm. Risk factors included history of smoking (54%), history of heart disease (51%), hypertension (41%), hyperlipidemia (34%), and chronic obstructive pulmonary disease (25%). Clamp time averaged 51 minutes. Forty-eight required no intraoperative transfusion, and 19 needed only autologous blood; the average 24-hour transfusion was 313 cc. Length of stay averaged 11 days, with a median of 8 days, and correlated with age, aneurysm size, and risk factors. The 30-day mortality rate was 4%. Death was associated with longer operative and anesthesia times and with age and risk factors. As calculated by life-table analysis to 5 years, 96.8% of aneurysms thrombosed. No aneurysm expanded, became symptomatic, nor ruptured. Perioperative platelet, fibrinogen, and fibrin split product assays show no evidence of disseminated intravascular coagulation or consumptive coagulopathy.

Conclusions: Staple exclusion and bypass of abdominal aneurysms as described in this study is safe and effective. There has been neither aneurysm expansion nor rupture, and the technique reliably leads to thrombosis of aneurysms without coagulopathy. (J VASC SURG 1995;21:623-34.)

Staple exclusion of abdominal aortic aneurysms (AAAs) via the extended posterior lateral operative approach combines several controversial elements in the performance of AAA surgery. The conventional resection uses the transperitoneal approach with opening of the AAA sac, suture ligation of lumbar arteries and inferior mesenteric artery, and construction of in-lying graft anastomoses to the proximal aortic cuff and distal runoff arteries, followed by wrapping of the graft in the thrombectomized aneurysm sac. Deviation from the aneurysmorrhaphy technique by exclusion with induced thrombosis of the AAA and concomitant bypass was developed to decrease the blood loss associated with opening the aneurysm and to minimize aortic dissection in the induction of AAA thrombosis and was used primarily in patients at poor risk. When performed initially with axillofemoral bypass and outflow ligation only, this was associated with ultimate expansion and rupture in a small number of cases.[1] Modification led to direct inflow and outflow exclusion by suture technique, with immediate bypass grafting via the posterior lateral retroperitoneal route.[2,3]

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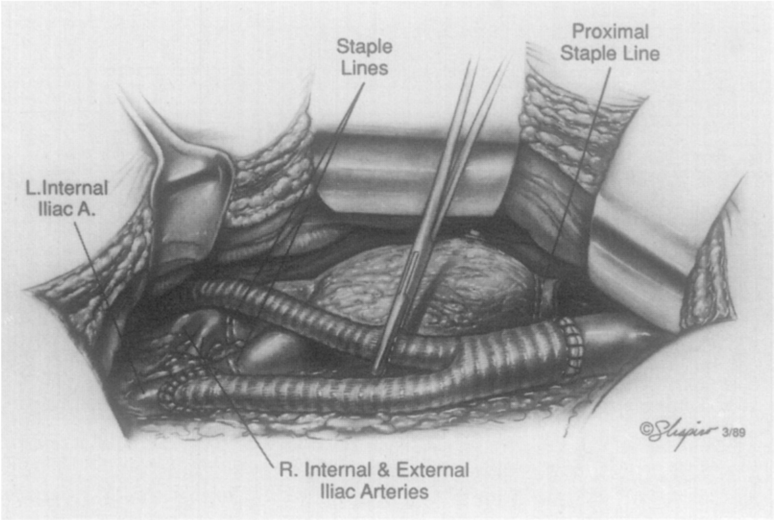

Fig. 1. Proximal AAA cuff, both iliac artery aneurysms stapled, left external iliac anastomosis completed, and right graft limb passed via retroperitoneal tunnel to right femoral artery. We no longer clip, nor suture, IMA as depicted in this illustration. Reproduced from Ernst CB and Stanley JC, eds. Current therapy in vascular surgery. St. Louis: Mosby–Year Book Inc., 1991:305. Reprinted with permission.

Table I. Deaths

	Died (n = 4)	*Survived (n = 96)*	*Difference*	*Significance*
Age (yrs.)	79	70	+9	$p < 0.001$
Anesthesia time (min.)	367	247	+120	$p < 0.001$
Operative time (min.)	281	187	+94	$p < 0.001$
Cross-clamp time (min.)	80	49	+31	$p = 0.08$
AAA size (cm.)	7.2	5.4	+1.8	NS
RBCs cc	750	300	450	NS
Autologous	0	100		
Homologous	750	200		
LOS	10	11		

LOS, Length of stay.

The application of linear stapling devices, as used in gastrointestinal surgery, to aortoiliac arterial surgery was initially described by the authors of this study.[4] In the performance of staple exclusion of the AAA, the dissection of the proximal aortic cuff, as well as the distal iliac arteries, especially if aneurysmal, is minimized by the necessity to develop only a plane of dissection 1 cm in width to accommodate the anvil of the stapler. Once exclusion is effected by stapling, the extent of the proximal dissection is dictated by the requirements of the length of infrarenal aorta available to the proximal graft anastomosis.

A prospective study was designed to analyze commonly used parameters for comparative evaluation of techniques of AAA surgery to include both open and nonresective operations performed via both the retroperitoneal and transperitoneal approaches. Additionally, possible alterations of the normal clotting mechanisms, specifically induced by thrombosis of the excluded AAA, were investigated. Furthermore, the ultimate short- and long-term fate of the excluded aneurysm was documented and tracked by duplex scanning. This may have significant relevance to the behavior of AAA excluded by endoluminal aortic grafting, a minimally invasive procedure designed to achieve AAA exclusion.

MATERIAL AND METHODS

One hundred consecutive cases of elective infrarenal staple exclusion of AAAs performed via the retroperitoneal approach were prospectively reviewed from April 1989 to November 1993. Thirty-five expanding, ruptured, inflammatory AAAs, as well as those requiring simultaneous visceral artery

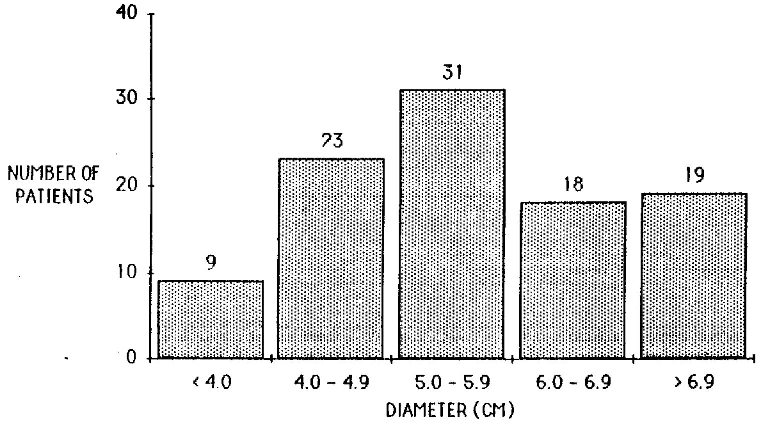

Fig. 2. Distribution of AAA size in 100 cases with diameter in centimeters.

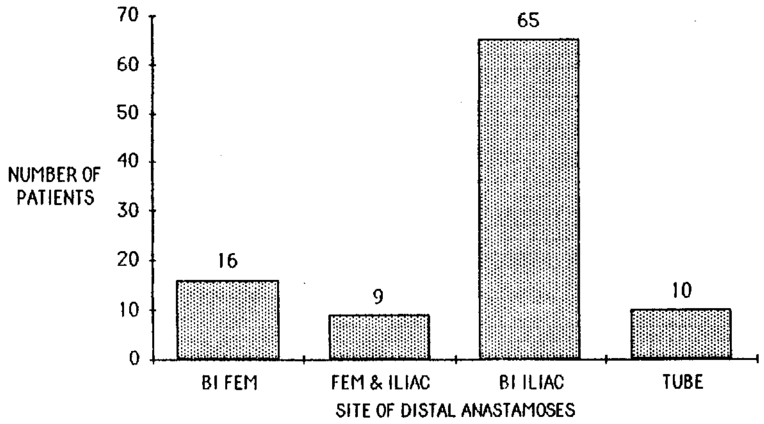

Fig. 3. Graft configuration. Site of distal anastomosis in 100 cases.

reconstructions (mesenteric, renal), performed during the same period, were excluded from the study group. Comprehensive preoperative cardiopulmonary evaluation was routine. Preoperative preliminary laboratory pulmonary evaluation was performed at the discretion of the consulting pulmonologist.

Consulting cardiologists directed preoperative cardiac evaluation, as well as perioperative and postoperative cardiac management. Preoperative cardiac workup included echocardiography in all patients. In the asymptomatic 50 to 60 year old group with a negative history of heart disease and normal echocardiography and electrocardiography results, the stress test was omitted. When the echocardiography result was abnormal or the patient had symptoms of heart disease, a history of angina, congestive heart failure, or previous myocardial infarction (MI), stress testing was done. Treadmill stress testing with thallium was preferred if the patient was able to exercise and achieve an adequate heart rate, otherwise, dipyridamole thallium radionucleotide studies were carried out. When deficits were noted in the distribution of more than one vessel or involving large areas of myocardium, cardiac catheterization was done. Patients older than 60 years, even if they had no symptoms of coronary artery disease (CAD), generally have had stress testing. If the patient had ischemic electrocardiographic changes, or angina at a workload of less than 7 METS (7 times resting metabolic workload or equivalents), cardiac catheterization was performed, but was used selectively for less than 10 METS. Patients who achieved more than 10 METS workload before ischemic symptoms or ST segment changes (if mild) were considered to have CAD, but multivessel or left main CAD was believed to be unlikely, and catheterization was unnecessary. Patients with three-vessel CAD with impaired left ventricular function, including left anterior descending artery stenosis, as well as left main coronary artery

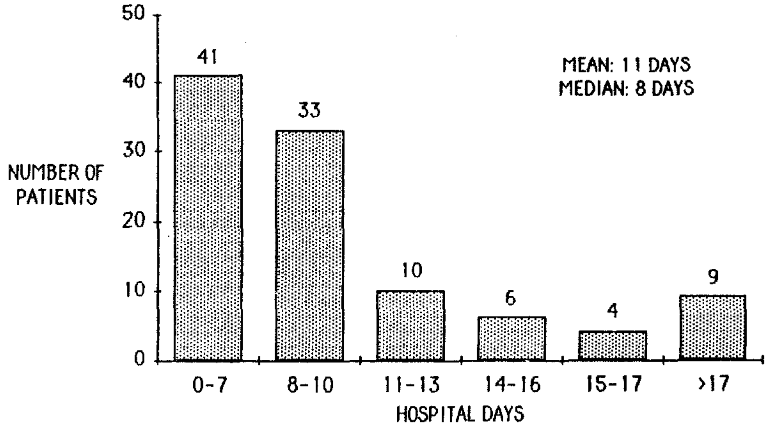

Fig. 4. Length of stay. The mean was 11 days, the median was 8 days, and 75% were 10 days or less.

Table II. RBC replacement

Authors	*Mean CC*	*None (%)*	*Homologous (%)*	*Autologous only (%)*
Present	313	48	33	19
Shah et al.[3]	406	32	51	17
Cambria et al.[12]				
Transperitoneal	921	*	36	*
Retroperitoneal	910		33	
Sicard et al.[14]				
Transperitoneal	1235	—	—	—
Retroperitoneal	853	—	—	—

*Routine use of autotransfuser in 80% of cases.

stenosis were considered for coronary artery bypass grafting (CABG) before AAA surgery.

Seventy five patients underwent ultrasound imaging, 17 underwent computed tomography (CT) scanning with contrast, eight underwent both ultrasonography and CT. In addition to these studies, all patients had preoperative aortography. Autologous red blood cell (RBC)-donation (1 to 2 units) was carried out in most patients within 3 to 4 weeks of surgery. Pulmonary artery catheters were placed before operation in 99 patients and were removed before the patients left the intensive care unit. Hemograms, partial thromboplastin times, prothrombin times, serum fibrinogen, fibrin degradation products, and platelet counts were documented before operation, in the recovery room, and on the first postoperative morning. Postoperative cardiac monitoring usually included daily cardiac enzymes (creatine phosphokinase, creatine phosphokinase–MB, lactate dehydrogenase) for 48 to 72 hours, as well as electrocardiography on the first postoperative day and serially if abnormal. Electrocardiographic monitoring was routine for 72 hours and longer as necessary. Standard risk factors were recorded and included age, sex, AAA size, heart disease (previous MI, congestive heart failure), chronic obstructive pulmonary disease (COPD), history of smoking, diabetes mellitus, hyperlipidemia, hypertension, and chronic kidney disease or failure. Anesthesia time, operating time, cross-clamp time, and total homologous and autologous RBC replacement (24 hours) were documented. Complications were reviewed, and correlation with risk factors and variables of the surgical procedure were analyzed.

All survivors (n = 96) were studied by duplex scanning, with the exception of three patients who were lost to follow up. Although early in the study duplex scanning used the Ultrasonix 750 SD (Ultrasonix, Yonkers, N.Y.), all patients were ultimately evaluated by the ATL Ultramark 9 Ultrasound System (Advanced Technology Laboratories, Inc., Bothell, Wash.), more recently with high-definition imaging, with use of both the 2.25 Mhz phased array probe and 3 Mhz curved linear array probe. Sagittal and transverse views were obtained and recorded on videotape and hard copy. Each study used both gray-scale and color-flow scanning. Areas of flow

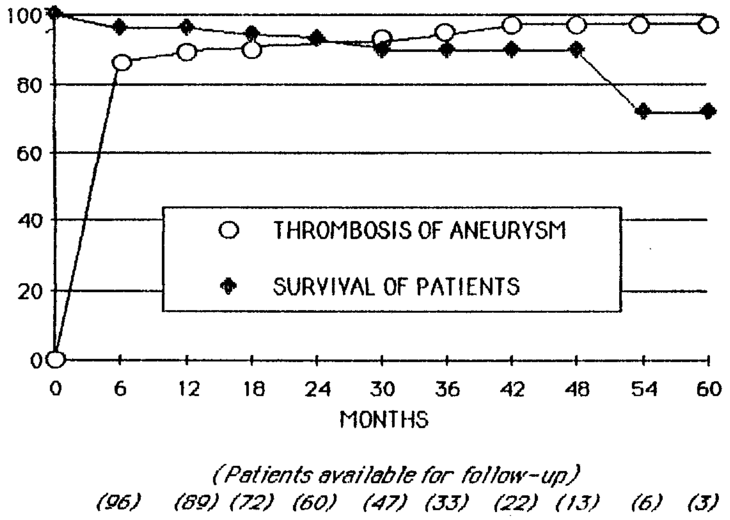

Fig. 5. Cumulative thrombosis and survival (Life-table analysis to 5 years).

Table III. Complications

Complication	*No.*	*Age*	*AAA size*	*AT*	*OPT*	*X ct*	*RBC*	*Autologous*	*Homologous*	*LOS*
MI	5	67	5.7	281	221	65	350	150	200	14
No MI	95	71	5.5	250	190	50	325	100	225	11
ARF	8	69	6.3	316	265	64	725	150	575	19
No ARF	92	71	5.4	242	184	50	300	100	200	10
Pulmonary	17*	73	5.9	260	198	54	350	100	250	15
No pulmonary	83	70	5.4	250	190	51	325	100	225	10

AT, Anesthesia time; *OPT*, operating time; *X ct*, cross-clamp time.
*Seventy-one percent had a history of smoking.

were determined by the presence of pulsatile color flow and Doppler signal. Quarterly surveillance was performed on all patients during the first year and continued indefinitely in those demonstrating persistent flow until no further flow within the excluded aneurysm was demonstrated. Those with no flow within the stapled AAA at 1 year or later were then studied annually. Serial measurements of the diameter of the excluded AAAs with flow were performed in the transverse and sagittal views. The authors reviewed the videotapes of the examinations to confirm the original interpretations and measurements as part of this study. Mapping of the flow sites within the excluded AAA was performed, and preoperative aortograms were reviewed for inferior mesenteric artery patency in patients in whom flow was detected.

Our operative procedure has been previously described[8] and uses a left posterior retroperitoneal incision starting at the lateral rectus border and extending to the eleventh or tenth interspace, depending on the proximity of the AAA to the renal arteries. Anterior mobilization of the left kidney and ligation of the lumbar tributary of the left renal vein at the level of the left renal artery are followed by mobilization of the infrarenal aorta, which is limited to a space sufficient for application of the aortic clamp and extended distally to accommodate the 1 cm–wide anvil of a 30 or 55 mm linear stapling device. This provides an intervening aortic segment, which comfortably permits an end-to-end anastomosis after aortic transection (Fig. 1). The inferior mesenteric artery is neither ligated nor clipped. Dissection of the iliac arteries, usually adherent to the subjacent iliac veins, is limited to the width of the stapler anvil (1 cm). If there is a high index of concern regarding possible atheromatous trash from the AAA, the iliac arteries are mobilized and clamped first, which results in earlier administration of heparin. Every effort was made to preserve bilateral hypogastric artery flow, either by distal common iliac end-to-end anastomosis, or by stapling of the distal common iliac artery,

Table IV. Postoperative thrombosis of 11 excluded AAA with flow

Patient	*Preoperative AAA size (cm)*	*Excluded AAA size (cm)*	*No. postoperative studies*	*Surveillance time (mos.)*		*Total follow-up*
				Thrombosis	*Persistent*	
1	8.13	8.1	8	–	27	27
2	5.0	5.0*	6	–	38	38
3	4.8	3.8	4	–	12	12
4	8.0	7.1*	10	–	39	39
5	5	4.0	8	12	–	30
6	5.2	5.1	11	42	–	63
7	6	3.6	2	–	7	7†
8	8.7	3.8	6	4	–	23
9	4.7	2.9	5	17	–	27
10	7.3	6.8	9	33	–	47
11	4.5	4.2	4	5	–	14

*Confirmed by CT; size same as determined by ultrasonography.
†Died 7 months after AAA surgery following coronary artery bypass grafting.

which provides retrograde hypogastric flow via an external iliac end-to-side anastomosis (Fig. 1). This was sometimes possible only on one side. Intravenous heparin (5000 μ) was used without protamine reversal and monitored during operation by activated clotting times and partial thromboplastin times in the recovery room. Distal anastomoses were constructed via the primary left retroperitoneal incision. When necessary, a right retroperitoneal counter incision was used for better exposure of the right common iliac bifurcation and external iliac artery. Groin incisions were used for femoral anastomoses with anastomoses performed to the deep femoral artery when the superficial femoral artery was occluded.

Early (same day) extubation was performed by the anesthesiologist in the operating room, recovery room, or intensive care unit. Blood replacement, when necessary, used autodonated RBCs first, supplemented by homologous RBCs if needed. Most patients autodonated 1 to 2 units RBCs within 3 to 4 weeks of surgery. Those patients not autodonating received homologous RBCs. Intraoperative RBC recovery systems were not used. Intraoperative indications for transfusions were not fixed but were based on the patient's hemodynamic condition, including arterial blood pressure, pulse, pulmonary arterial wedge pressure, and urinary output as assessed by both the anesthesiologist and surgeon, and were evaluated relative to estimated RBC loss. These parameters were again used after operation, as well as hemoglobin and hematocrit determinations. Generally, HGB 8.0 to 8.5 gm within the first 24 postoperative hours prompted transfusion; however, our threshold for transfusion in patients with significant CAD was sometimes triggered at a slightly higher HGB level.

Statistical methods. Categorical data were compared by use of the chi-square test. Numerical data were compared by use of the Student t test. Differences were considered to be statistically significant when $p < 0.05$ was demonstrated. Long-term survival of patients after AAA exclusion is reported by use of Kaplan-Meier actuarial life-table analysis. The same method was used to calculate cumulative thrombosis rate of the excluded AAA over time. Calculations were performed with the aid of commercially available software with use of a personal computer.

RESULTS

Men comprised 81% of this cohort, and women comprised 19%. Average AAA size was 5.5 cm, the median was 5.1 cm. Almost three quarters of the AAAs measured between 4 to 7 cm, with 19% being larger than 7 cm (Fig. 2). There were 65 aortobiiliac, 16 bifemoral, and 10 tube grafts placed (Fig. 3). Average age was 70 years. The incidence of heart disease was 51%, hypertension 41%, and COPD 25%. Fifty-four percent smoked, 34% had hyperlipidemia, and 14% had diabetes mellitus. The operative mortality rate was 4%, with nonsurvivors 9 years older than survivors (Table I). Of the four patients who died, three had a history of previous MI, one as recent as 6 months before surgery. Cause of death in that patient involved a cerebrovascular accident, pneumonia, congestive heart failure, and transient kidney failure. The second patient, who had previous myocardial infarction, hypertension, and remote cerebrovascular accident, had intraoperative bilateral renal atheromatous emboli, anuria, and death caused by hyperkalemia and cardiac dysrhythmia. A third patient with a history of recent carotid endarterec-

Table V. A, Life-table analysis of 96 patients surviving aneurysm exclusion

Interval (mo.)	*Deaths*	*Lost to F/U*	*Patients at risk*	*Survival (%)*
0-6	4	3	96	96
7-12	0	17	89	96
13-18	1	11	72	94
19-24	1	12	60	93
25-30	1	13	47	90
31-36	0	11	33	90
37-42	0	9	22	90
43-48	0	7	13	90
49-54	1	2	6	72
55-63	0	8	3	72

F/U, Follow-up.

tomy, hypertension, COPD, and recent MI (6 months) died 72 hours after cecal perforation on the seventh postoperative day as a result of diffuse ischemic colitis involving the entire colon with "skip areas." The fourth death was lung-related in an octogenarian with advanced COPD. Age, anesthesia time, and operative time, were significantly greater in the nonsurvivors. Although cross-clamp time and AAA size were also greater, this difference was not statistically significant between the two groups. Average anesthesia, operative, and cross-clamp times for the entire series were 251, 191, and 51 minutes, respectively. Twenty-four–hour blood replacement averaged 313 cc for the entire series, with 48 patients receiving no RBCs, 19 given only autologous RBCs, and 33 given homologous RBCs (Table II). Comparative data with other studies of AAA surgery performed via retroperitoneal and transperitoneal routes, as well as a series analogous to this group with use of suture exclusion technique via the retroperitoneal approach are outlined in (Table II). Same-day extubation was possible in 65% of our patients; 46 in the operating room, 6 in the recovery room, and 13 in the ICU. The average length of stay of the entire cohort was 11 days, with a median of 8 days. Preexisting heart disease raised the average length of stay to 14 days, and COPD raised the average to 16 days. Patients with AAA greater than 6 cm spent an average of 13 days in the hospital and with AAA less than 6 cm, 9 days. Forty percent of the entire cohort were discharged at 7 days or less, and 74% at 10 days or less (Fig. 4).

Postoperative thrombocytopenia, hypofibrinogenemia, increased fibrin degradation products, and disseminated intravascular coagulation were not observed in any patient in this study group. There were no staple line failures (hemorrhage) in this study group. Graft surveillance demonstrated no limb thromboses or false or true aneurysms at proximal or distal anastomoses within the duration of this ongoing study. No major injury to the iliac veins occurred. Major complications included four instances of MI. Older age was not a predisposing factor, nor were AAA size, anesthesia time, operative time, cross-clamp time, and RBC replacement (Table III). Two patients had had remote MIs, one followed by CABG. In another patient who had had an MI 6 months before operation (his second MI), an MI was a terminal event after cecal perforation caused by ischemic colitis at 7 days after operation. A fourth patient underwent urgent staple exclusion for continuing atheromatous emboli 8 weeks after MI. She had a postoperative MI from which she recovered. Postoperative anemia was not a factor in the development of postoperative MI. Two of these three patients had diabetes, one had hyperlipidemia. Renal failure (ARF), defined by a serum creatinine level greater than 2.5 mg/dl, occurred after operation in eight patients, with trends noted with longer operative and cross-clamp times and RBC replacement, none of which were statistically significant (Table III). No patient required dialysis, but one patient died on the second postoperative day of cardiac dysrhythmia as a result of hyperkalemia as a result of "trash kidneys" and anuria (creatinine of 5.8 mg/dl). All other instances were transient, with the highest recorded creatinine of 6.7 mg/dl. Seventeen percent had major pulmonary complications; 13 of these patients actively smoked, two were reformed smokers, and two were nonsmokers. COPD was present in 13 patients, and previous pneumonia was present in three. Postoperative pneumonia occurred in eight patients, and atelectasis occurred in 11 patients; reintubation and respirator support were necessary twice. This was not influenced by age, AAA size, operative parameters, nor RBC loss. ARF and pulmonary complications extended the length of stay by 9 and 5 days, respectively (Table III). There were

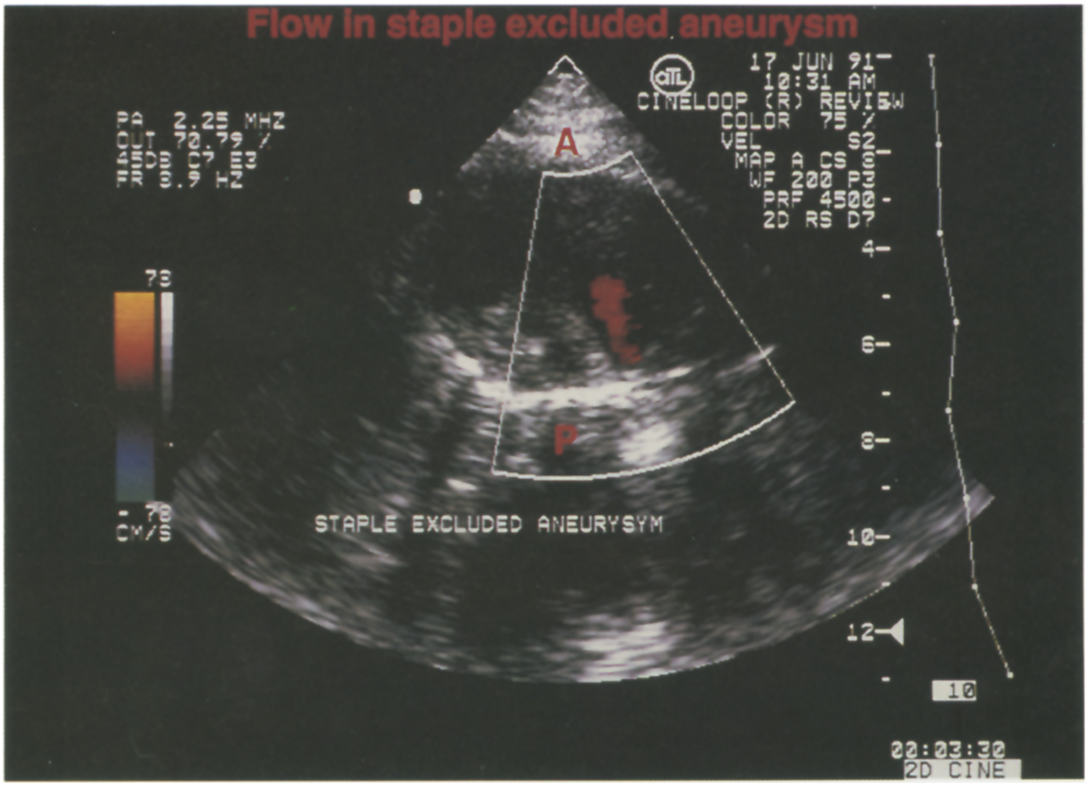

Fig. 6. Color flow sonogram of largest area of persistent flow (lumbar artery) noted in series. Thrombosis at 42 months.

two gastrointestinal complications, of which one was related to the retroperitoneal incision. The peritoneum, which was flimsy, tore during mobilization and was repaired in several sections with separate continuous sutures. A repaired 3-inch segment of peritoneum in the postoperative period tore, resulting in a Richter's hernia of the sigmoid with partial strangulation of the colonic wall. This was diagnosed and repaired transabdominally on the tenth postoperative day, with segmental sigmoid resection, colostomy, mucous fistula, and later restoration of bowel continuity. The graft was separated from the fistula by fibrous healing at the time of reexploration, and there has been no evidence of graft sepsis in 36 months of follow-up. The second gastrointestinal complication involved ischemic colitis of the entire colon, with "skip areas" and cecal perforation on the seventh postoperative day, resulting in multiorgan failure and death.

In 11 patients postoperative ultrasound examination demonstrated some flow within the excluded AAA, of which six have thrombosed during subsequent surveillance. Five were first noted at 3 months, one at 6 months, two at 9 months, and three at 12 months. Table IV documents the surveillance time to thrombosis in the six patients who had thrombosis and time to current persistent flow in five patients. The five patients who currently demonstrate flow continue to be studied with ultrasonography every 3 months. Life-table analysis indicates that at 6 months, 87.2% of the patients had had thrombosis; whereas, by 42 months 96.8% had occlusion (Fig. 5). These data are listed in Table V. Thus far, the longest period from initial detection of flow to thrombosis was 42 months, in the patient who seemed to have the highest flow velocity in the entire series (Table IV, Fig. 6). Precise determination of the peak systolic velocity detected within the excluded AAA is difficult because of the examiner's inability to determine the exact angle of insonance of the Doppler probe relative to the retroperitoneally located excluded AAA. Review of the ultrasound tapes permitted mapping of the location of persistent flow, and these sites corresponded to lumbar artery locations (Fig. 7). In an effort to investigate a patent inferior mesenteric artery as a possible source of retrograde collateral flow into the excluded AAA, the senior author reviewed the preoperative aortograms of all 11 patients with subsequent flow. The inferior mesenteric artery was patent in only one, and this did not

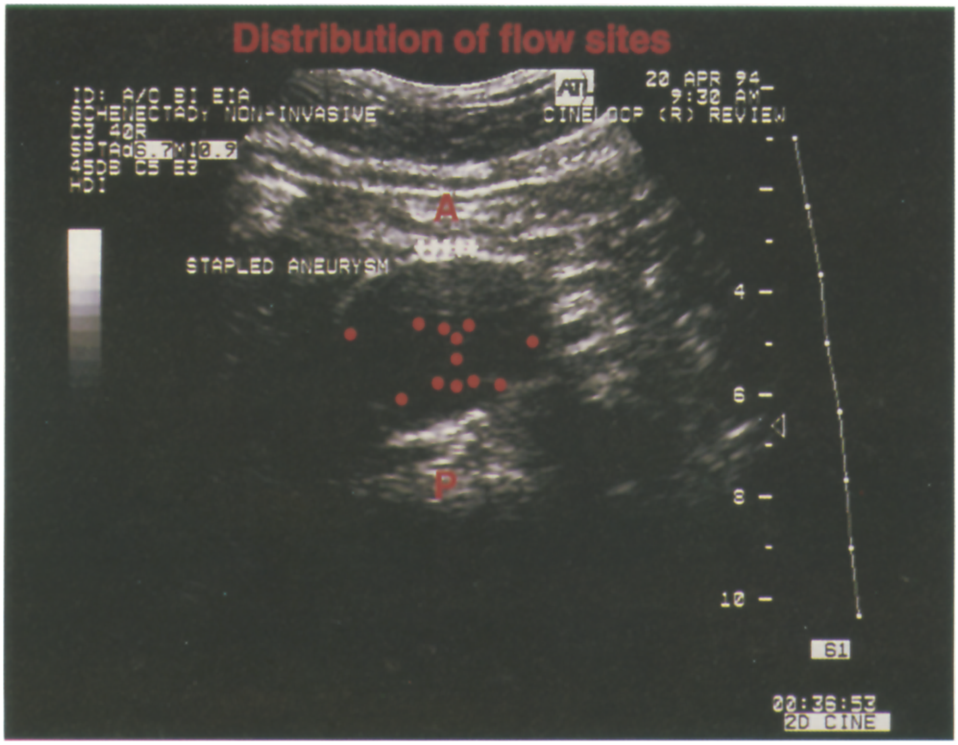

Fig. 7. Distribution of lumbar artery flow sites superimposed on transverse view of thrombosed excluded AAA.

correspond to the location of persistent flow noted on the sonogram. Transverse diameter of the excluded AAA was measured in the 11 patients with persistent flow. No increase in diameter was noted compared with the preoperative diameter nor on serial examination (Table IV).

This ultrasound study has documented no evidence of AAA expansion relative to time or persistence of flow, nor has there been clinical suggestion of expansion in long-term follow-up. No excluded AAA has ruptured, leaked, nor required reexploration for this problem in this patient cohort.

DISCUSSION

Nonresective staple exclusion of AAA via the posteriolateral retroperitoneal approach combines three controversial techniques of AAA repair. Ligation and exclusion of AAA, initially attempted by Sir Astley Cooper[5] in 1817, was first successfully performed by Blaisdell et al.[6] Although endoaneurysmorrhaphy with an in-line graft anastomosis from within the opened aneurysm sac has become the standard operative procedure, Karmody et al.[1] reported 60 cases of nonresective outflow occlusion leading to AAA thrombosis with axillobifemoral reconstruction. Three of these AAA expanded and ruptured, leading to disrepute for nonresective therapy. A 20% rupture rate and 10% operative mortality rate is quoted for the exclusion technique in a contemporary text of vascular surgery published in 1993.[7] However, the safety and durability of the nonresective principle has been documented by Shah et al,[3] who reported 280 cases of exclusion and bypass via the retroperitoneal route. Expansion requiring reoperation occurred in two patients, both of whom were given anticoagulants; one patient had portal hypertension, and the other had persistent internal iliac flow. This has provided the foundation for the staple modification as presented here, which has specific advantages as elaborated below. A preliminary report by the authors of this study indicated that exclusion could be accomplished safely by use of the stapling technique presented in this study.[8] Aortic and iliac artery dissection can be minimized by use of 30 and 55 mm linear stapling devices, as routinely used in gastrointestinal surgery. Mobilization of a 1 cm arterial segment, only wide enough to allow insertion of the anvil of the device, helps to avoid injury to the subjacent iliac veins. The length of the infrarenal aortic neck is the decisive factor in determining the extent of cephalad aortic dissection. The dissection requirements include 3 cm between the

Table V. B, Life-table of cumulative thrombosis of 96 survivors of aneurysm exclusion

Interval (mo.)	*Thrombosis (no.)*	*Lost to F/U*	*At risk*	*Patent (%)*	*Thrombosis (%)*
0-6	82	4	96	12.8	87.2
7-12	2	1	10	10.1	89.9
12-18	1	1	7	8.5	91.5
19-24	0	0	5	8.5	91.5
25-30	0	1	5	8.5	91.5
31-36	1	0	4	6.4	93.6
37-42	1	2	3	3.2	96.8
43-60	0	0	0	3.2	96.8

F/U, Follow-up.
At this point (60 months), all living patients show thrombosis of AAA.

upper limit of the AAA and the renal arteries to allow for aortic cross-clamping, AAA stapling, and end-to-end anastomosis by use of parachute technique. The stapling techniques can be applied to short cuffs but may necessitate suprarenal aortic clamping in juxtarenal AAAs. It is important to staple both iliac outflow arteries completely.

Further controversy surrounds the preferred route of aortic exposure for elective, infrarenal AAA operations. The retroperitoneal approach to the aortoiliac arteries was described initially by Cooper,[5] later used by Dubost[9] in the first reported successful AAA repair, and resurrected by Rob in 1963.[10] Nevertheless, the standard operative approach has remained transabdominal by use of the endoaneurysmorrhaphy in-line grafting technique mentioned above. The original description of the extended posterior retroperitoneal approach by Williams,[11] was primarily reserved for patients at poor risk. However, this has emerged in some centers as the preferred operative exposure for all patients.[3,12] Conversely, Cambria et al.,[14] in a comparative study of the transperitoneal and retroperitoneal techniques, was unable to demonstrate an advantage of either method in terms of operative and aortic cross-clamp times, transfusion requirements, cardiopulmonary death, return to oral alimentation, and hospital length of stay. Although a compelling case for the retroperitoneal exclusion technique was later presented by Shah et al,[3] most vascular surgeons still preferentially use the transabdominal endoaneurysmorrhaphy method.

Risk factors in this patient cohort demonstrate a predominance of men with an average age of 70, with the oldest patient undergoing operation being 88 years of age. Smoking seemed to play a significant role in both preexisting cardiopulmonary disease and postoperative complications involving these systems (Tables III). Anesthesia time, operative time, and aortic cross-clamp times were tracked and compare favorably with those reported in both groups (transperitoneal and retroperitoneal) by Cambria et al.[12] Average anesthesia time of 251 minutes compares favorably with the 264 minutes reported by Cambria.[12] He also reported average cross-clamp times of 72 minutes via the retroperitoneal route and 66 minutes via the transperitoneal route as compared with 51 minutes reported in this series. Excluding rather than opening the AAA, whereby avoiding suture ligation of the lumbar, middle sacral, and inferior mesenteric arteries is helpful in decreasing cross-clamp time and RBC loss. Actual operative time averaged 191 minutes (60 minutes less than anesthesia time) and probably reflects a learning curve on the part of the anesthesiologist and operating room personnel in preparing and positioning the patient for the retroperitoneal approach. This "lag" period has progressively been shortened. The operative mortality rate was 4%, which is comparable to other similar series.[3,12] Advanced age, extended anesthesia, operative, and cross-clamp times, and higher RBC replacement were statistically significant factors in the nonsurvivors (Table I). These data imply that avoidance of technical problems, if possible, and more careful selection of patients for this operation should realistically maintain the elective operative mortality rate at 2.5% to 4%. Avoiding these pitfalls is often more easily stated than achieved.

The 24-hour operative and postoperative transfusion requirements appear to be less than reports of others involving transperitoneal and retroperitoneal approaches in both open and exclusion techniques[3,12-15] (Table II). However, the postoperative period covered in their data was not indicated and therefore may be longer than the 24-hour RBC replacement reported in this study. Nevertheless, homologous transfusions were necessary in only one third of our cases. Same-day extubation was achieved in 65% of our patients, which is slightly higher than Cambria's transperitoneal (61%), but less than his retroperitoneal group (78%). Length of hospital stay averaged 11 days, the median was 8 days, and 40% were discharged within 7 days and 74% within 10 days of surgery (Fig. 4). Cambria[12] and Sicard[14] report similar average lengths of stay in their retroperitoneal approach group (10 to 11 days); whereas Cambria's transperitoneal approach group averaged 12.5 days. Our length of stay was also higher in patients with preexisting heart (14 days) and lung (16 days) disease. Patients with AAA greater than 6 cm also had lengths of stay averaging 3½ days longer than AAA less than 6 cm. Review of the four patients with acute postoperative MI suggested a slightly older average age and slightly longer anesthesia, operative, and cross-clamp times, which were not of statistical significance (Table III). Two of the four had high cardiac risk factors, with one having had an MI 6 months and the other 8 weeks before surgery. RBC replacement differences were also not significant, but average length of stay increased to 14 days (Table III). The eight patients with kidney failure had larger aneurysms, longer anesthesia, operating, and cross-clamp times with greater RBC replacement reflecting more complex AAA repairs. None required long-term dialysis, but one patient died of "trash kidneys" incurred after cross-clamping, at which time anuria developed. Unfortunately atheromatous embolization to the renal, hypogastric, or distal arteries is no less frequent with this technique than the open technique. If there is any suspicion of irregular intraaortic atheromatous material on operative examination, preoperative aortography, or CT scanning, iliac occlusion and administration of heparin should precede aortic cuff mobilization. Seventy-one percent of the pulmonary complications were in patients with a history of smoking, which extended hospitalization by an average of 5 days.

Flow in the excluded AAA was detected in 11 cases, 45% of which were noted on the first postoperative ultrasound examination, and seen in all 11 cases by 1 year. Six subsequently thrombosed, leaving five currently with flow during ongoing surveillance. Life-table analysis, which accounts for the four deaths and three patients lost to follow-up, demonstrates a thrombosis rate of 87.2% at 6 months, 89.9% at 12 months, and 96.8% at 37 to 60 months (Table V, Fig. 5). Within the duration of the study thus far, this has been stable, with further thrombosis anticipated. Direct measurement of excluded AAAs with flow show no increase in diameter with time, nor were there any thrombosed AAAs larger than preoperative diameter (Table IV). However, precisely valid peak systolic velocity cannot be accurately determined within the excluded AAA because the true Doppler probe angle of insonance is difficult to establish. AAA size did not statistically correlate with persistence of flow nor with peak systolic velocity of flow as measured within the retroperitoneally located thrombosed AAA. Color-flow and ultrasound imaging within this limitation is indirectly suggestive of quantitative flow within the excluded AAA, and no trend was established between this and probability of thrombosis. However, it is to be emphasized that this is not a quantitatively accurate observation. Flow into the AAA sac comes from the lumbar arteries (Figs. 6 and 7), not from retrograde flow via a patent inferior mesenteric artery communicating with superior mesenteric arteries or pelvic collateral circulation. Only one of 11 patients with flow had a patent inferior mesenteric artery on preoperative aortography. It is suggested by these observations that inflow is provided by lumbar collateral circulation arising from above the stapled AAA sac, and outflow occurs via patent lumbar arteries within the excluded aneurysm.

It has been stated that the dissection required to mobilize the proximal aortic cuff with the exclusion technique is excessive.[13] As indicated above, proximal cuff dissection requirements are limited to 1 cm, the width of the stapler anvil, and as much additional aortic cuff as is necessary to perform the proximal anastomosis, depending on the relationship of the upper boundary of the AAA to the renal artery, as well as the space occupied by the aortic clamp. The use of a ribbon retractor over the thrombosed, excluded AAA and selective use of parachute aortic suture technique will enable the proximal anastomosis to be performed with relative ease. The thrombosed AAA is not an encumbrance to anastomotic technique in the capacious retroperitoneal space. Dissection to exclude the aneurysmal aorta is greatly facilitated by a limited requirement of only 1 cm to accommodate the stapler anvil width. This often occurs in an area where the subjacent iliac veins are intimately fused to one of the overlying iliac arteries or aneurysms. Once stapled, preferably proximal to the internal iliac origin, the iliac anastomosis may be placed end to side to the proximal external iliac artery, which provides retrograde flow into the internal iliac artery and prograde flow via the external iliac artery into the distal arteries. Depending on the anatomic configuration of the patient, this often can be accomplished at the right common iliac level from the left retroperitoneal approach. If necessary, a right counterincision can be used to perform this maneuver at the distal right common iliac level, especially when exposure is obstructed by a large right iliac aneurysm. Twenty-five patients had femoral anastomoses with the graft easily tunneled under the inguinal ligament to the groin. In any event, dissection is minimized by use of the stapling technique. We have had no significant staple line hemorrhage requiring reexploration. These are routinely checked before closing, and rarely a reinforcing large hemoclip has been applied at the corner of a calcified aortic closure. All grafts have remained patent during this ongoing study period without ultrasound evidence of true or false aneurysm at either proximal or distal anastomoses. Because of the capacious nature of the retroperitoneum, the course of the graft can be smooth without kinks and angulation and without complication as a result of extrinsic compressive factors.

This study suggests that staple exclusion of elective, infrarenal AAA is a safe and effective operative procedure. It is associated with low morbidity and mortality rates and decreased RBC replacement, achieved by not opening the aneurysm sac, which avoids bleeding from the lumbar, middle sacral, and IMA arteries, as well as the sac edge. This has decreased homologous RBC replacement to one third of the patients in this study. Postoperative pulmonary and cardiac work requirements appear to be decreased, and length of stay appears to be diminished in most patients (Fig. 4). Exclusion of the aneurysm sac has resulted in proved thrombosis in 96.8% of the cases by life-table analysis, with the expectation that further thrombosis will occur in the five excluded AAA with persistent flow currently under surveillance. Flow within the excluded AAA, although not precisely quantified, appears to be low. There has been no documented AAA expansion nor rupture in this study group. Those cases with documented rupture reported by others had a different operative procedure from the one presented in this study, which is not comparable to the current technique as described. A recent review of 36 cases of AAA rupture after axillofemoral bypass and aortic exclusion revealed that the aorta had been ligated in only four.[16] Furthermore, rapid thrombosis of the excluded aneurysm has not been shown to induce a consumptive coagulopathy in this series of patients. Fibrinogen levels and platelet counts have remained normal after induced aneurysm thrombosis with use of the staple exclusion technique. No excluded AAA in this patient cohort nor in our total experience with AAA exclusion has become infected.

It is also suggested that these data may have relevance to expectations for excluded AAA behavior after insertion of endoluminal grafts, which also are designed to induce AAA exclusion and thrombosis. Ultrasound surveillance of cases with endoluminal graft placement is a readily available, noninvasive modality to document excluded AAA thrombosis or associated complications that may develop with this new technique. As the availability of spiral CT increases, this too should be helpful in documenting arterial "leaks" after AAA exclusion. Analysis of our experience, herewith presented, suggests that staple exclusion via the extended posterolateral retroperitoneal approach, currently the procedure of choice in our practice, has significant advantages for both the surgeon and the patient in the elective repair of infrarenal AAA.

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